Original Article: Microgrid Control to Ensure Stability and Increase Flexibility in Storage Applications

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ABSTRACT

The purpose of this paper is to use energy storage resources in the microgrid to control its voltage and frequency. Today, due to the manifestation of the benefits of microgrids, the use of renewable sources and energy storage has increased; therefore, these systems must be able to control microgrids. The VBD method is proposed to coordinate these forces with energy storage to help regulate the voltage and frequency of the microgrid when necessary and to supply more power to the microgrid repeatedly. Therefore, new energy sources such as photovoltaics, wind turbines, or fuel cells are a real reason for generating electricity in these areas, and despite the initial cost of installing such new power generation equipment, the above reasons have made the use of these resources convincing in remote areas. Because the imbalance of power generation and consumption causes deviation and change of network frequency and may cause serious damage to frequency sensitive loads, so one of the important issues in microgrids separate from the network is power and frequency control.

Introduction

Concerns about climate change have led to major changes in electricity generation and consumption patterns. Many countries planned to reduce greenhouse gas emissions by 20% in 2020, and set targets in their economic plans for the production and consumption of various fuels [1-3]. There are plans for major changes at both the transmission and distribution levels in recent years and in the years to come, and it can be argued that power systems are undergoing a change in their nature, taking advantage of advances in renewable energy technology [4-6]. Low-carbon technologies, measurement, and communications are affected and supported by government policies [7]. These changes have also affected electricity networks, heating-cooling systems, and gas networks, and have increased the connection between

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these systems. On the other hand, they have led to the need for storage systems [8-10].

Transmission systems have been strengthened to transfer the power generated by clean and renewable energy power plants such as large wind farms, geothermal power plants, and solar thermal generation. At the distribution level, many smaller renewable generators (for example, fuel cells, photovoltaics, small hydropower generators, etc.) are connected to the grid, called distribution generators (DGS) or distributed energy sources (DERS), which are integrated into Distribution Systems. The radial nature of load distribution has changed the distribution system [11-13]. A microgrid is a set of load and small resource functions as a single control system that provides power to its local area. In urban facilities, the microgrid can be a single controllable unit that is able to respond to the needs of the transmission system in a matter of seconds [14-16]. For consumers, the microgrid can meet their special needs such as local voltage support, increase local reliability, increase productivity through the use of wasted heat, reduce feeder losses, and provide ready-to-use power supply functions. Microgrids bring many benefits to both consumers and network operators, including improved reliability by providing reliable power to the island itself during downtime and improved power quality. Microgrids also shorten the gap between production and consumption, thus reducing losses and shutdown management, and simplifying the maintenance process, in addition to using renewable energy sources [17]. Technologies and energy storage technologies offer many benefits. The microgrid control system is designed to control and support the activities of the system in two modes of island and operation connected to the distribution network of a power distribution company with very high safety and security. This control system can be formed on the basis of a central control system or it can be scattered on each island that forms a microgrid. When the island is disconnected from the main system, the control system must be able to control the local voltage level and output frequency at its nominal value and standard tolerance, calculate the difference between active and reactive power generation and consumption on the island, take the necessary measures to maintain network stability, protect the microgrid against errors, events, shutdowns and accidents, and keep subscribers' consumption at an optimal level [18-20].

In this paper, we aimed to study the microgrids and sources of energy production and storage in it, as well as the microgrids in the island state and to investigate the methods of controlling the voltage and frequency of the electrical system [21-23].

Island mode and microgrid independent operation

An important challenge is when the microgrid operates independently. This mode of operation is different from the one connected to the network in different ways. First, the microgrid must be able to meet all the energy requirements of the load at any time by performing the appropriate power distribution between the DG units (according to the production specifications of each) and if it fails to do so, it must be properly managed cut off unnecessary loads so the operation of the microgrid is not compromised. In this case, in order to overcome the continuous fluctuations of production and consumption in the face of possible events, they must provide power control of production units with automatic control equipment so that their power generation follows the consumer demand [24-26]. In addition, the microgrid must be able to regulate the frequency and voltage control, and to achieve this, it must be able to control the active and reactive powers. In stand-alone mode, microgrid dynamics depend heavily on connected sources and controllers of electronic power converters. A microgrid has the facilities and infrastructure to operate as a small power system [27-29].

The only major difference with conventional power grids is that the microgrid is known as a weak grid due to its low inertia moment. In a power system based on electric machines, after the active power is disturbed, the kinetic energy of the generator rotor, which is stored in normal operation, begins to rotate and increases or decreases its speed depending on the amount of disturbance. The moment of inertia is equivalent to high generators and there is more opportunity to balance the active power and thus dampen the frequency fluctuations [30-32]. But in a microgrid based on electronic power converters, the transistor regime produces a smaller time constant, resulting in much more frequent frequency fluctuations. The main technical problem that microgrids with renewable energy sources face is balancing the active and reactive power to overcome frequency and voltage fluctuations [33-35].

Microgrid with central controller

Existing methods for microgrid control can be divided into two main categories based on the use of telecommunication equipment or not using them. Among the telecommunication-based methods, we can mention two methods of centralized control and main/follower control. In the centralized control method, in addition to generators, energy storage systems and other devices required for operation, the microgrid must have a central control system to operate similarly to the load distribution center in the power system. The central controller provides proper management for the DG units, and makes all the decisions needed to use the sources and control the amplitude and phase angle of their output voltage. It is also able to integrate microgrids with smart grids through telecommunication channels. The connection between the control center and the DG units is established using a wireless telecommunication system [36-38].

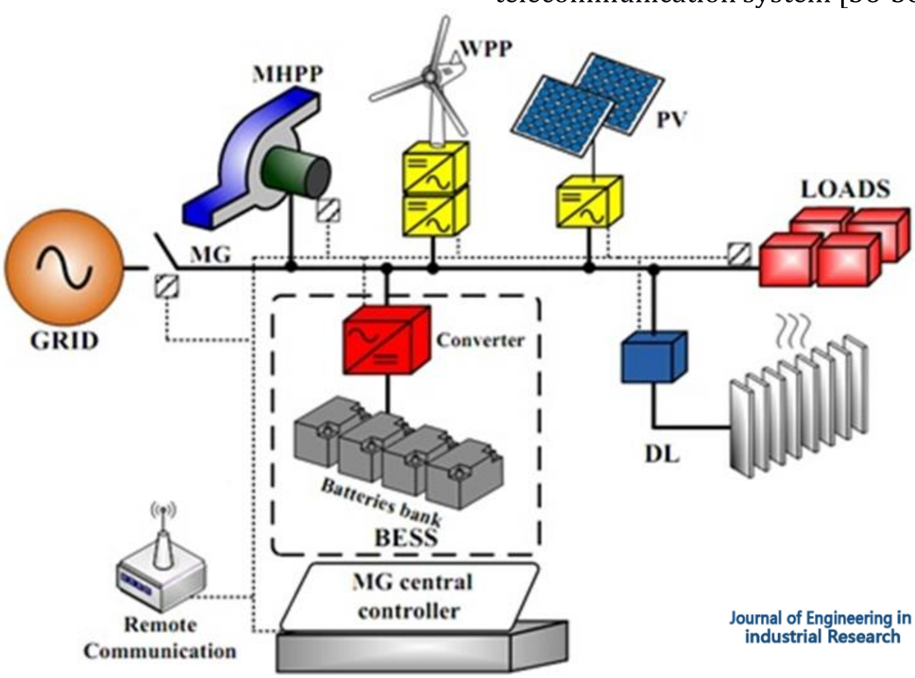

Figure 1. Microgrid with central controller

There is a master controller in the master/follower control strategy that allows other follower controllers in the subnet to receive and execute settings and commands from this master controller through telecommunications. Figure 2 shows this control strategy. The voltage source is the main controller. When connected to the network, the system voltage and frequency are stabilized by the mains and the microgrid will not need to adjust the voltage and frequency [39].

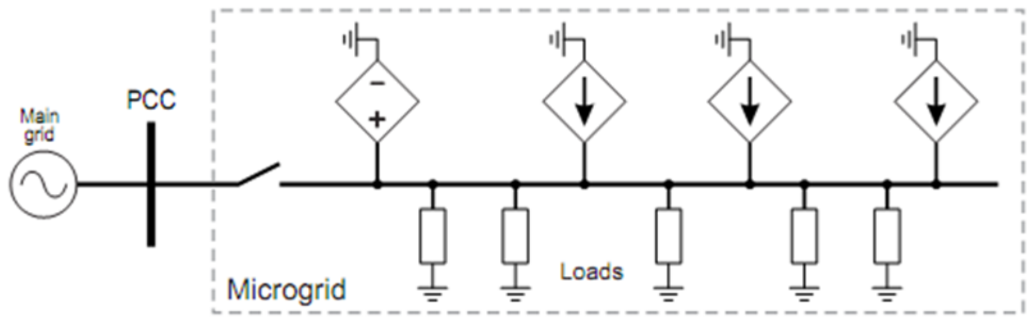

Figure 2. Schematic of a microgrid based on main/follower control

Storage voltage drop control

VBD control has been developed for low voltage microgrids, which is characterized by the use of resistive microgrid lines mainly including the connection between the active power P and the voltage range of the Vg network. Hence, P/Vg is used instead of frequency control (P/f droop control) to share active power between units, including storage elements, in the network. It is considered a public storage element and the control strategy is an initial control strategy [40-42].

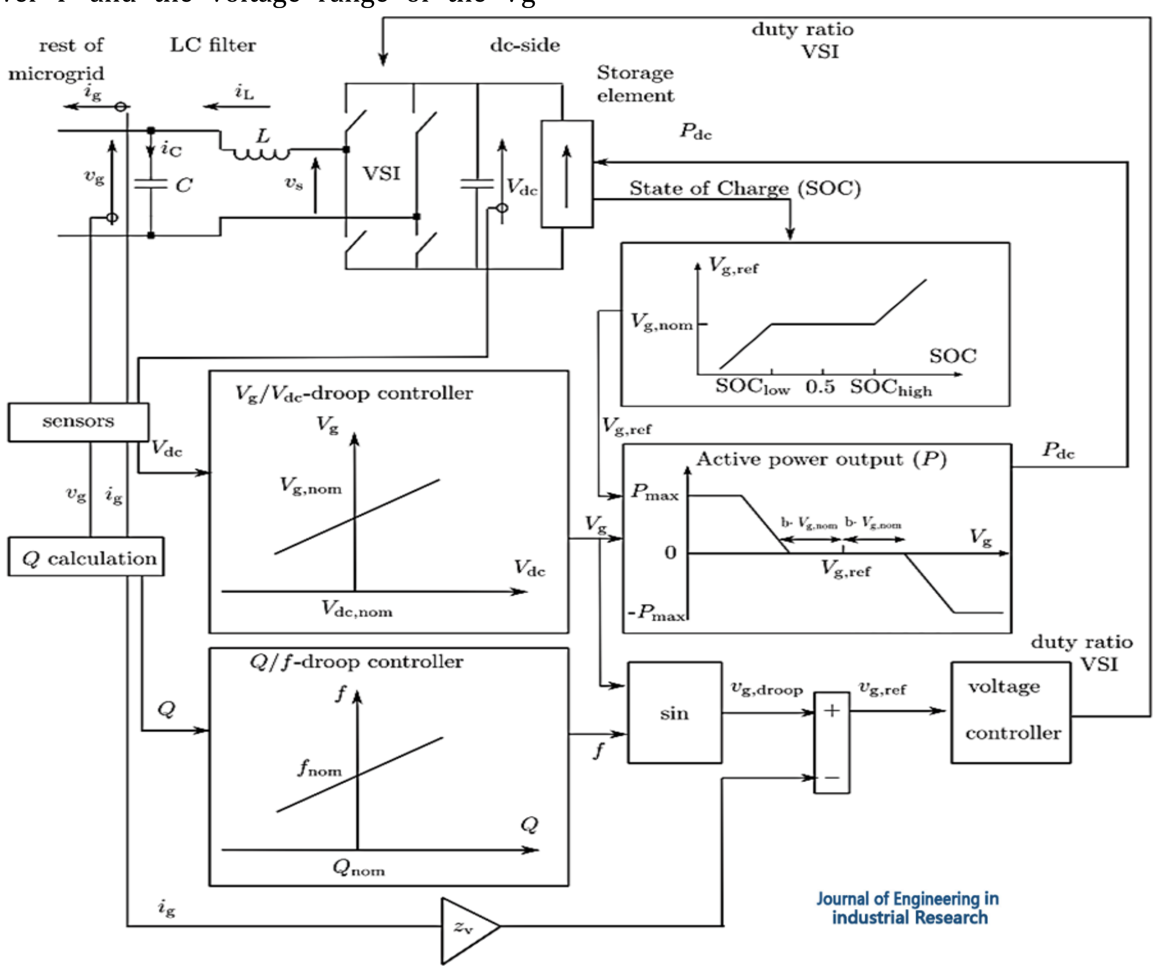

Figure 3. Voltage and frequency control scheme diagram

The main difference with the previously developed VBD controller is that the charge element (SOC) of the storage element must be considered [43-45]. An overview of the control scheme is shown in Figure 3. However, the Pdc/Vg droop controller is different in storage elements. The storage elements are first equipped with a Pdc/Vg droop controller that determines the active power output of the storage element, which sets Vg; ref to Vg; nom.

Simulation results

In the following figures, a storage element with a maximum output/input power of 4 kW and a maximum capacity of 10 mAh (i.e., a very small storage element to magnify and compress the effect of SOC changes) is presented. The initial SOC is equal to 0.5. Voltage values (± 10% Vg; nom) are violated for a period of less than, for example, 12.1 <t <16 seconds. This indicates the need to properly adjust the flexibility of all network elements (fixed power bands of DG unit, loads and storage elements as well as storage buffer). In the first-time interval of 0 <t <1.4 seconds, the SOC is the storage element between 0.3 and 0.7, which is the dead band of the Vg; nom/SOC curve. Hence, Vg; nom = Vg; ref remains constant. As in this time period, the terminal voltage of the storage element is slightly less than its nominal value, the storage element delivers power to the network. Next, the SOC droops to less than 0.3, leading to a decrease in Vg; ref (Vg; nom> Vg; ref) compared with SOC. This changes the Pdc/Vg curve to the left and reduces power delivery. At t = 3.5 seconds, the load decreases, which increases the terminal voltage. As Vg; ref> Vg; the storage element starts charging. At t = 5s it decreases even more, which leads to an increase in the consumption of storage equipment [46-48].

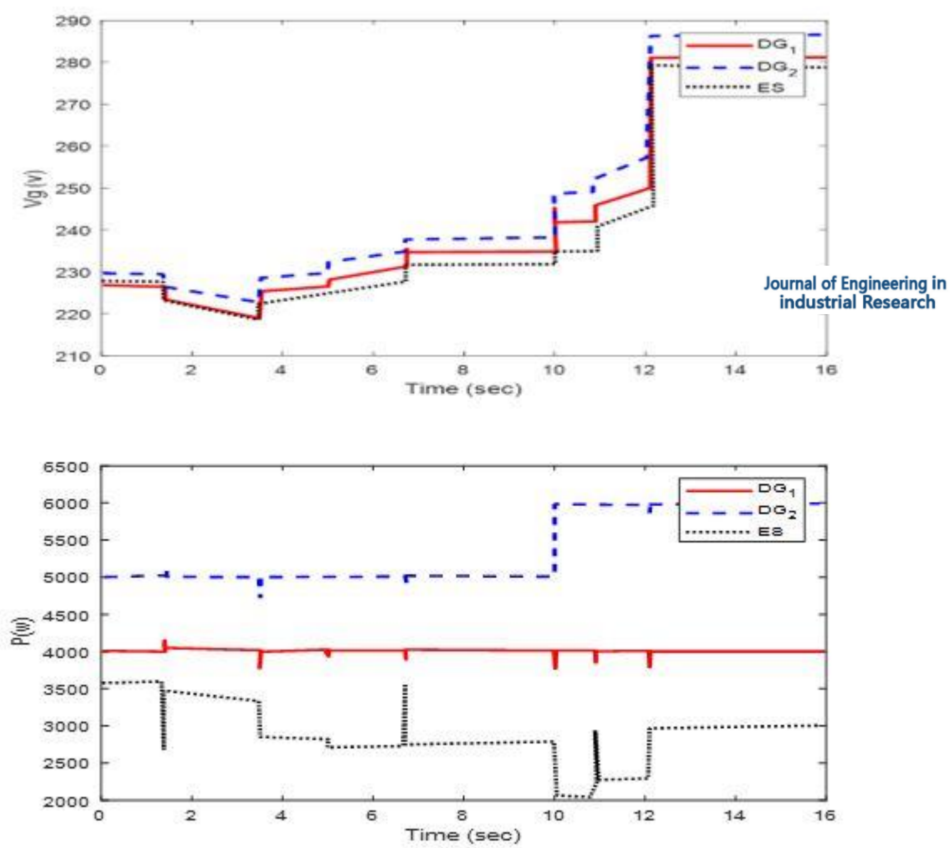

Figure 4. Dynamic changes of microgrids with storage unit without DG flexibility

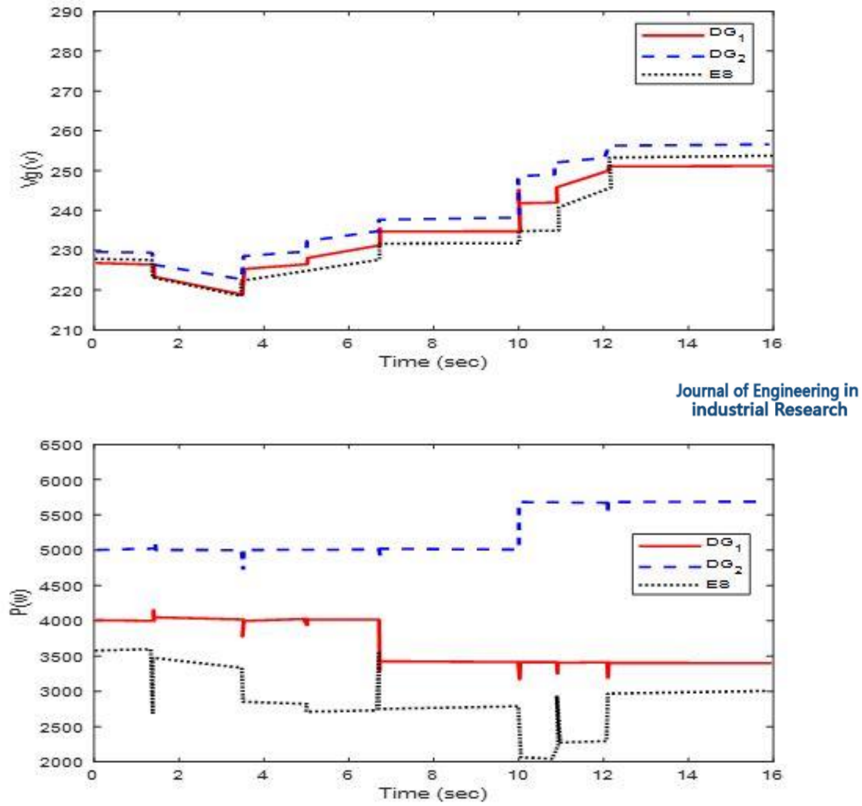

Figure 5. Dynamic changes of microgrids with storage unit and DG flexibility

Conclusion

Today, due to the increasing influence of distributed generation in the power grid and also the emergence of an island state due to switching for various reasons such as error or predetermined switching, strategies for the operation of distributed generation are of particular importance. It depends on both economic and electricity market reasons and maintaining the stability of the network. In this study, after the complete introduction of micro-networks and distributed generation and types of distributed generation, as well as how to model them in simulation, we examined a specific strategy in the operation of distributed generation when the micro-network became an island. In this paper, a voltage-based droop control for storage elements in island microgrids is presented. This storage controller works well with controlling the same voltage-based droop across other microgrid elements such as controllable loads and DG units. As the microgrid control is unrelated and the storage elements contribute to the microgrid control in a coordinated manner with other network elements, this strategy offers the benefits of a consistent control strategy to the microgrid stability.

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